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# Younger Dryas cooling and fluvial response (Maas River, the Netherlands) (extended abstract)

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## Introduction

The morphology of a river floodplain is determined in general by its gradient, sediment load, grain size and discharge. Climate, sea level and tectonics can influence these factors. Tectonic uplift is a prerequisite for erosion and terrace formation, but it has to be regarded as a long-term and more gradual process. The presence of distinct Late Glacial terraces along the Maas (= Meuse) indicates that the river incision must have been stepwise. This stepwise erosion can be explained by climate changes and a low sea level, superimposed on a long-term tectonic uplift. Climate-induced fluvial changes were previously established by Vandenberghe (1987 and references cited there). This paper describes the effects of the Younger Dryas climatic changes on the Maas River system in the Netherlands ( Limburg province, north of Venlo; Fig. 1).

The Maas valley was previously studied by, amongst others, Schelling (1951), Pons (1957), Van den Broek & Maarleveld (1963), Westerhoff & Broertjes (1990), Bohncke et al. (1993), Berendsen et al. (1994) and Kasse et al. (1994).

At the start of the Younger Dryas a strong decline in summer temperature occurred (Bohncke et al. 1987, 1993). The presence of initial ice-wedge casts and frost cracks at Bosscherheide points to a mean annual temperature between −2 to −5 °C and, at least local, permafrost conditions (Figs 1, 4). The degradation of the Younger Dryas local permafrost and the formation of large-amplitude involutions have been dated between 10 880 and 10 500 BP (Bohncke et al. 1993). The establishment of the permafrost may also have occurred during the same time interval, but it cannot be excluded that local permafrost already penetrated the soil before 10 880 BP, during the later part of the Allerød. Bohncke et al. (1993) concluded that more intense frost action in the soil occurred after 11 300 BP.

The lower (especially summer) temperature and the decline of the pine forest cover will have led to a lower evapotranspiration at the start of the Younger Dryas. In combination with a possible increase in precipitation (Bohncke & Wijmstra 1988) larger amounts of melt water during spring will have been discharged by the Maas during the shortened snow melting period. Furthermore, the deeper frost penetration and local development of permafrost will have reduced the water storage capacity of the soil. These factors resulted in higher discharges in general and in more frequent and higher peak discharges.

At the transition from the Younger Dryas to the early Holocene the winter and annual temperatures rose very rapidly. Around 8600 BP the annual temperature had risen to at least 8 °C (Van Geel et al. 1980/1981) and the climate was oceanic and comparable with present-day conditions.

## Description and discussion

The Younger Dryas climatic cooling has been registered in the Maas valley in the following manners (Fig. 4):

### *Change in channel pattern*

The Younger Dryas terrace is separated from the Allerød terrace by a rather straight, 2–3m high terrace scarp (Fig. 1). The fluvial surface morphology of the Younger Dryas terrace is characterized by straight to slightly curved paleochannels which are typical for a braided river system. This surface morphology distinguishes the Younger Dryas floodplain from the previous Allerød floodplain with its well-developed mean-

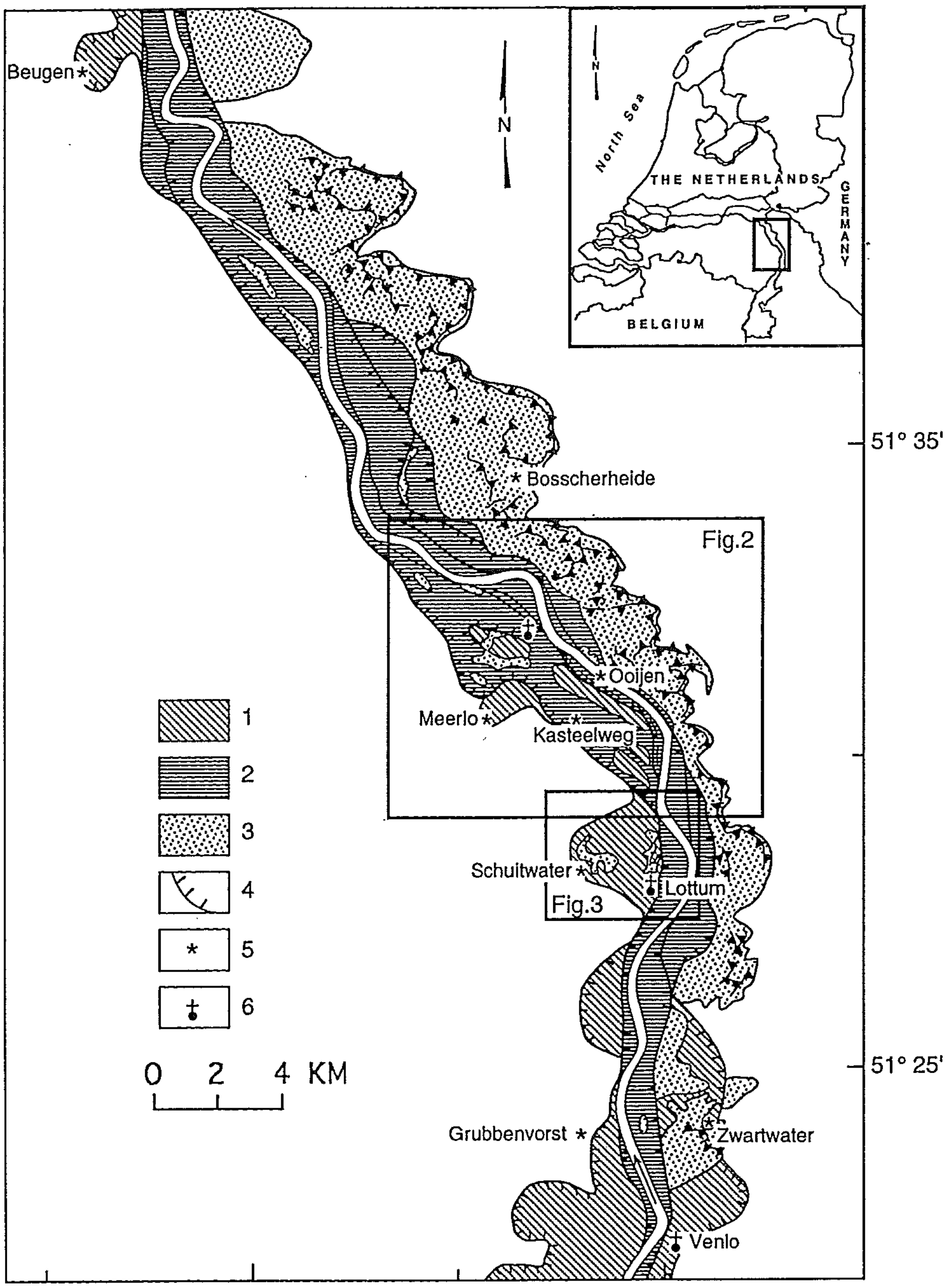


*Fig. 1.* Generalized morphological map of the Maas valley in northern Limburg. Note the curved terrace scarps (= meander scars) of the Allerød terrace and the more straight terrace scarps (= braided channel scars) of the Younger Dryas terrace. 1 = Allerød terrace, 2 = Younger Dryas terrace and Holocene floodplains, 3 = mostly Younger Dryas eolian sand and dune ridges (marked by triangled lines), 4 = terrace scarp, 5 = investigated site, 6 = town or village.

der scars (Figs 1, 3, 4). The increase in discharge and the discharge fluctuations are held responsible for the abrupt changes in the fluvial system. The river system reacted to the new hydrological situation by changing from single-channel meandering into multi-channel braided. In this way the Maas enlarged its stream capacity and could cope with the higher peak discharges.

The Younger Dryas terrace is generally found 2–3m below the Allerød terrace indicating that considerable erosion occurred in the valley associated with these higher peak discharges (Fig. 4). This rapid erosion can be explained by the limited availability of sediment in the channels because of the presence of a vegetation cover. Although the forest cover had become more open in comparison with the Allerød period, most of

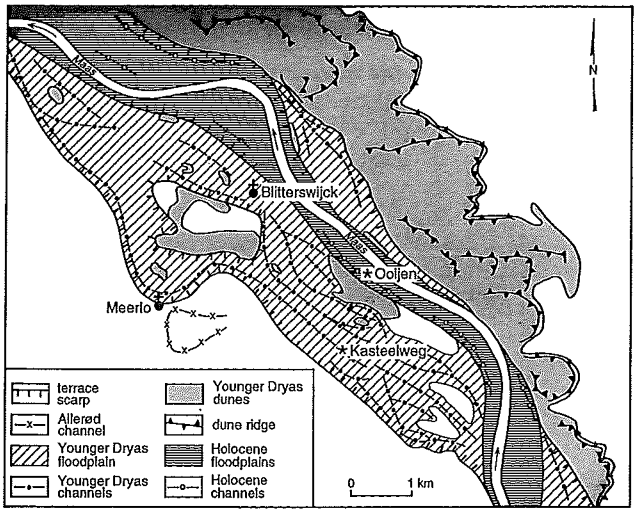


*Fig. 2.* Morphological map of the Younger Dryas braidplain at Blitterswijck (Fig. 1). Note the straight paleochannels, the remnants (= islands in white) of older terraces in the braidplain and the Younger Dryas dune belt on the east bank of the Maas.

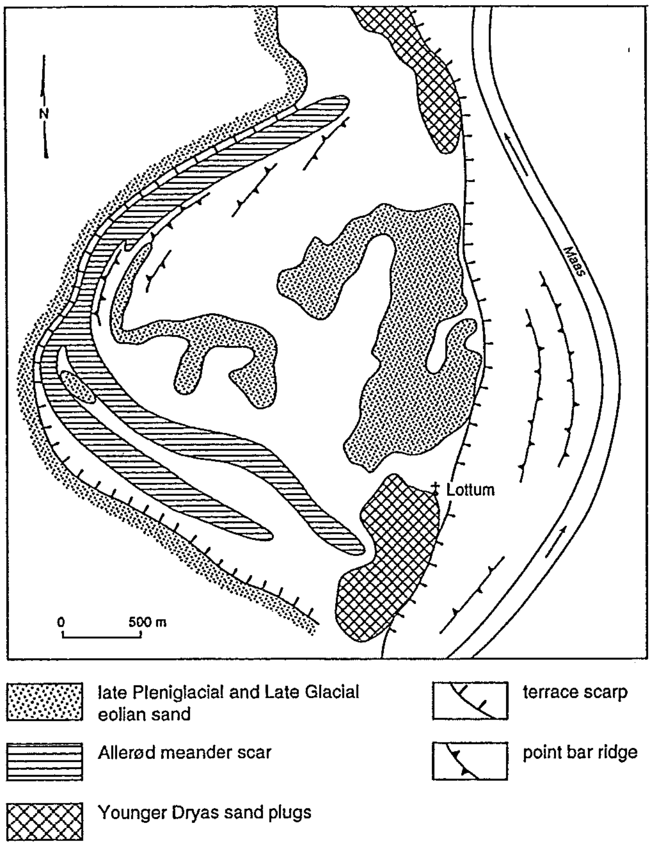


*Fig. 3.* The Younger Dryas chute cut-off of the Allerød meander at Lottum (Fig. 1).

the land surface outside the river floodplain remained vegetated with herbs and shrubs during the Younger Dryas (Bohncke et al. 1988, 1993). The formation of parabolic dunes in the second part of the Younger Dryas (see below) also points to the presence of a vegetation cover.

Fine examples of the Younger Dryas braidplain have been found in the environs of Blitterswijck (Fig. 2). The channels are shallow (up to 2m deep) and often have a clastic infilling. They are underlain by coarse sand and gravel of the active braiding phase. A 2m organic fill was found locally in scour pools in the abandoned braided channels. Palynological investigations revealed a late Younger Dryas age of the base of the infill, indicating that the braided river system was active during the Younger Dryas (Kasse et al. 1992). The bars in between the channels consist of gravelly sand. Fining-upward sequences are not pronounced and generally short. The islands and bars in this floodplain are locally covered by river dune sand, which was blown out of the multi-channel plain during low water.

The rapid temperature rise in the early Holocene caused an increase of the evapotranspiration. Because of the higher winter temperatures less snow accumulated and the amount of snow melt water decreased. As a consequence the discharge, and especially the peak discharges, of the Maas decreased. The wide Younger Dryas braidplain became oversized in relation to these lower discharges and part of it was abandoned. Most likely, the deepest channels of the former braidplain persisted and were used by the early Holocene Maas which developed a low-sinuosity meandering course.

*Chute cut-off of existing meanders*

The high-sinuosity meandering channel that existed during the Allerød was abandoned by numerous chute cut-offs at the beginning of the Younger Dryas. Higher peak discharges are the probable cause for this. Such discharges also caused the pointbar surfaces of the meandering river plain to be flooded and eroded, and a new straight floodplain was formed (Figs 3, 4). By the chute cut-off process the Maas established a shorter course with a higher gradient and the river was therefore able to transport larger amounts of water in a shorter period. The flow in the meandering channel diminished and eventually the meander loops were abandoned. Sands were deposited in the entrances and exits of the meander loops and formed

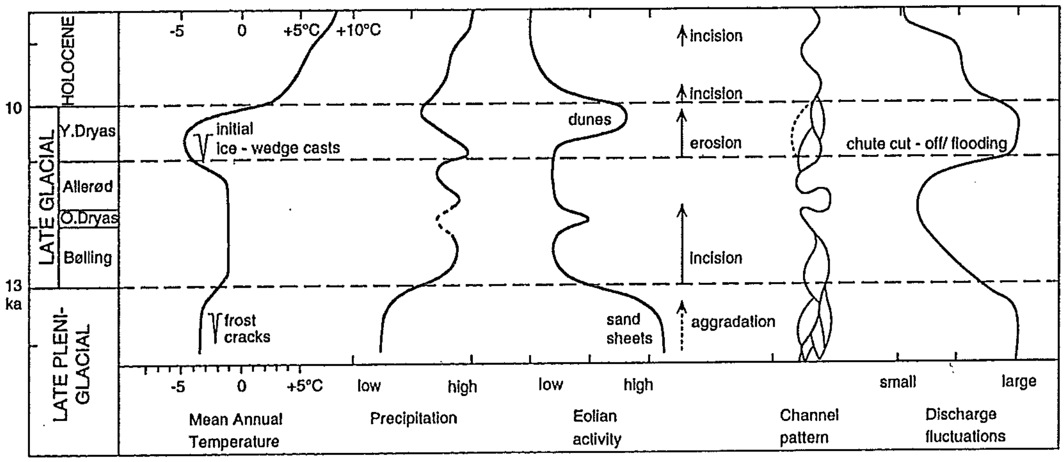


*Fig. 4.* Summary of the Late Glacial fluvial development of the Maas in northern Limburg, the Netherlands. Mean annual temperature is based on periglacial structures and vegetation. Eolian activity and precipitation are qualitative estimates based on the sedimentary record and partly on lake level changes (Bohncke & Wijmstra 1988). Discharge fluctuations are inferred from climate, channel pattern and the sedimentary record.

sand plugs behind which oxbow lakes developed, as can be seen for example in the chute cut-off meander of Lottum (Fig. 3). Fine-clastic deposition prevailed in these lakes during the Younger Dryas, since only suspended sediment could enter the environment by overbank flooding.

*Flooding of older terraces*

The higher snow-melt peak discharges of the Maas were able to inundate areas which were previously above the flood limit, for instance Late Glacial or late Pleniglacial terraces. At Bosscherheide a fluvial loam was deposited over the Allerød humic soil and the Younger Dryas involutions. The presence in this loamy bed of *Classopollis* pollen, derived from Lower Cretaceous rocks in the upper reaches of the Maas, clearly demonstrates the regional character of the flooding in the Maas valley and of the upland erosion in France. This flooding phase has been dated between 10 880 and 10 500 BP (Bohncke et al. 1993).

*Lithological change in neck cut-off meanders*

Closely related to the silt deposition on older terraces is the change in sediment type in the infilling of neck cut-off meanders. Because of the higher peak floods of the Maas not only older terraces were inundated but also channels, abandoned already during the Allerød, were flooded. At Beugen (Fig. 1) a gyttja of Allerød age at the base of the oxbow lake infilling is erosively overlain by a gray, fine sandy, calcareous clay. This lithological break between the gyttja and the clay correlates palynologically with the start of the Younger Dryas (Kasse et al. 1992). This clay also contains *Classopollis* pollen. It represents a new phase of fluvial activity in the meander scar. Fluvial inundations by the Maas resulting in clay deposition could evidently reach the channel after a period of organic accumulation. During the Allerød the sedimentary conditions in this oxbow lake were very quiet and only organic sediment accumulated in a rather deep lake environment. At the Allerød-Younger Dryas transition, however, peak discharges in the Maas valley became so high that they could overtop the sand plugs at the entrance and the exit of the abandoned meander. The current velocity in the oxbow lake was low, since only sandy clay was deposited from suspension. The Allerød channel morphology itself was not modified.

*Widespread eolian deposition*

On the east bank of the Maas valley an up to 4km wide, sand-sheet belt occurs with parabolic dunes on top, lying on older Late Glacial or late Pleniglacial deposits (Figs 1, 2). The dune morphology is characterized by parabolic forms, especially at the eastern (downwind) margin of the sand sheet, where the dunes are up to 10m high. The parabolic morphology indicates firstly that the dominant sand-transporting wind was from the west-southwest during the late Younger Dryas. The sedimentary structures in the sand sheet are dominated by horizontal bedding and low-angle cross-bedding. Large-scale slip faces, which are formed at the lee side of dunes, have rarely been found, perhaps due to a lack of exposures in the parabolic ridges. Secondly, the parabolic dunes indicate that the eolian sand was trapped by vegetation beside the floodplain.

A peat layer underlying the eolian deposit at Bosscherheide allows to date the start of the eolian deposition just after 10 500 ± 60 BP (Bohncke et al. 1993). The top of the peat layer is characterized by an alternation of moss and sand laminae, which indicates that the vegetation was gradually overwhelmed by the eolian sand. This gradual transition implies the possibility of a diachronism for the start of the eolian accumulation.

The reason for this widespread eolian deposition is related to the channel geometry of the Younger Dryas floodplain. Because of the change from a single-channel meandering system (ca 200m wide) into a multi-channel braided system (1–2km wide) at the Allerød-Younger Dryas transition, the newly established, wide braidplain became subjected to deflation. The eolian sediment has probably been blown out of this plain onto the adjacent terraces during periods of low discharges. The eolian sediments within the floodplain had a low preservation potential, since they were easily eroded during periods of high discharges. Only at a few locations small Younger Dryas dunes were found on bars between the braided channels (Fig. 2). The accumulation of large amounts of sand in the dune field is closely related with the presence of the braided system. Because of the large width of the braidplain and the general north-south orientation, westerly winds were able to deflate the sand from this plain. The width of the Younger Dryas dune belt shows a good correlation with the width of the plain (Fig. 1). Deflation pavements have never been found in the braided plain. Therefore, fluvial reworking of this plain must have occurred repeatedly providing fresh material for deflation. These alternating processes of fluvial reworking and eolian deflation reveal that also during the late Younger Dryas the Maas had a strongly intermittent character with large discharge fluctuations.

The end of the eolian deposition in the Maas valley could not be dated until now. The deposition definitely had stopped before the Atlantic period (Teunissen 1983), but probably was restricted to the second half of the Younger Dryas. The large-scale deflation of the floodplain and the dune formation most likely stopped during the Younger Dryas-Preboreal transition because of the change in river pattern from a wide braided system into a narrow low-sinuosity meandering system in combination with the revegetation of the former braided floodplain.

## Conclusions

The Younger Dryas climatic cooling around 10 880 BP resulted in a lower evaporation and a decline of the pine forest vegetation. Together with a decrease in the water storage capacity of the soil by deeper frost penetration and permafrost development, it caused higher peak discharges of the Maas. The river adapted to the environmental changes by changing its channel morphology from meandering into braided. Large-scale abandonment of meanders occurred by numerous chute cut-offs. The higher peak discharges resulted in the flooding of older terraces and abandoned meanders. The floodplain was gradually lowered by erosion, because of the higher discharges in connection with a restricted sediment supply. During the second part of the Younger Dryas, after 10 500 BP, deflation from the braided floodplain became important and large river dune complexes were formed on the east bank of the Maas. The braiding phase and the associated deflation and eolian accumulation ended at the start of the Preboreal.

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